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ABSTRACT

The present study of personal context and continuity in twenty-three students' thinking builds upon data from a longitudinal study of the students' conceptualizations of ecological processes. Each student was interviewed eleven times from age 9-15 about the conditions for life, decomposition, and the role of the flower in plant reproduction. At the ages of 15 and 19, the students listened to what they said at the ages of 11 and 15 respectively and described how they thought their understanding had developed. The occurrence of characteristic individual elements in the students' conceptions can be followed as themes in the interviews year by year. They may relate to the content or be of a structural nature. The students could, as 15 and 19-year-olds, often reveal concrete personal experiences from an early age that they referred to again and again in the interviews. Even if there was a substantial conceptual development, there was also a very strong element of personal continuity. Conceptions developed at an early age seemed to be important for the future conceptual development. Therefore, an early introduction of some scientific concepts can help students to develop a deeper understanding of ecological processes. (Contains 10 references.) (Author/ASK)

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PERSONAL CONTEXT AND CONTINUITY OF HUMAN THOUGHT; RECURRENT THEMES IN A LONGITUDINAL STUDY OF STUDENTS' CONCEPTIONS

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Paper presented at the Annual Meeting of the National Association for Research in Science Teaching New Orleans, April 28 – May 1, 2000

Abstract
The present study of personal context and continuity in twenty-three students´ thinking builds upon data from a longitudinal study of the students' conceptualizations of ecological processes. Each student was interviewed eleven times from age 9-15 about the conditions for life, decomposition and the role of the flower in plant reproduction. At the ages of 15y and 19y, the students listened to what they said at the age of 11y respectively at the age of 11y and 15y and described how they thought their understanding had developed. The occurrence of characteristic individual elements in the students' conceptions can be followed as themes in the interviews year by year. They can have to do with the content or be of a structural nature. The students could as15 and 19-year-olds often reveal concrete personal experiences from an early age that they referred to again and again in the interviews. Even if there was a substantial conceptual development, there was also a very strong element of personal continuity. Conceptions developed at an early age seemed to be important for the future conceptual development. Therefore, an early introduction of some scientific concepts can help students to develop a deeper understanding of ecological processes.

BACKGROUND

In order to create teaching situations in during which students´ ideas about natural phenomena can be challenged, science educators must know more about the development of students' conceptions of different phenomena. Therefore, science education researchers need to stretch the duration of their research projects and study the same subjects over time in order to be able to make knowledge and value claims about students' long-term conceptual development. (Arzi, 1988).

Many research projects exploring students' learning about natural phenomena have been conducted around the world, however very few have been longitudinal in nature (White in press). Longitudinal studies can provide researchers to study the nature of the learning process, learning pathways and the influence of everyday experiences on students' long-term learning. Therefore, I started a longitudinal study of students´ conceptualization of ecological processes from the age of 9 to 15. These ecological processes comprised dealing with conditions for growth, decomposition in nature and the role of the flower in plant reproduction (Helldén, 1995; Helldén, 1998; Helldén, 1999) This paper reports findings that emerged from my continuing analysis of data from this longitudinal study. The objectives of the present research project are

- to analyze the interviews with the students in order to identify personal themes.
- to study how personal context and continuity can influence the students' conceptual development.

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DESIGN AND PROCEDURE

I, like many other researchers in science education, have found that clinical interviews can give in depth information on students' thinking about natural phenomena (Duit, Treagust & Mansfield, 1996). Over the course of my study I interviewed the same twenty-three students on 11 different occasions from grade 2 (9 years) to grade 8 (15 years) in the Swedish comprehensive school.

My experience of studies in similar classes had shown that it is important to meet the class on many occasions before the interviews start and to let the children be familiar with the purpose of the study. I therefore visited the class regularly during a period of six months before the study and showed the children that I was really interested in.

Prior to beginning my interviews of the students, I regularly visited the class of 9-year-old students during a six-month period. The purpose of these preliminary visits was to become familiar with the students and to show them that I was really interested in their thoughts about phenomena in nature. During the interviews I made it clear to them that I was interested in their thoughts per se, not whether the answer was right or wrong. To show the children that I was primarily interested in their thinking, I usually started the first question of the interview with the words: "What do you think .....?"

To challenge the students' ideas about the conditions needed for life, we grew plants in sealed transparent boxes. I started the interview with the question: "What do you think the plant needs to be able to grow in the box with glass lid pasted on?" Another question was: "What do you think will happen to the plant in the box if we plant it there and glue the lid on?" For my interviews about decomposition, I had soil, brown leaves and litter on a table in front of the students. The opening question was in this case: "What do you think will happen to the leaves on the ground in the fall?" Later during the interview about decomposition, I also asked the students: "What makes the leaves fall from trees in the autumn?" Concerning the interviews about the flower's role in reproduction, I carried through the first interview in meadow during a 'camp school'. During the other interviews about the flower's role I showed the students different kinds of wild flowers. The first question during these interviews was: "What is the importance for a plant to have a flower with color?" I did not teach the class, but I spent regular time with the students in the classroom and during excursions and fieldwork.

Already at an early stage of the research project, I found that there appeared interesting personal features in the students' descriptions year after year that seemed to be results of personal experiences that were hidden for the researcher. Why not asking the students themselves about such features?

A couple of hours after the last interview at 15 years of age, each student listened to audiotapes of my interviews with them four years earlier. I asked them to comment on their ideas at 11 years of age and explain why they said as they did. I also asked them to describe how they had developed their ideas after age 11 and what they thought had been of greatest importance in the development of their ideas. At age19, I interviewed the students again. I asked them these same questions after they had listened to my interviews with them at 11 and 15 years of age.

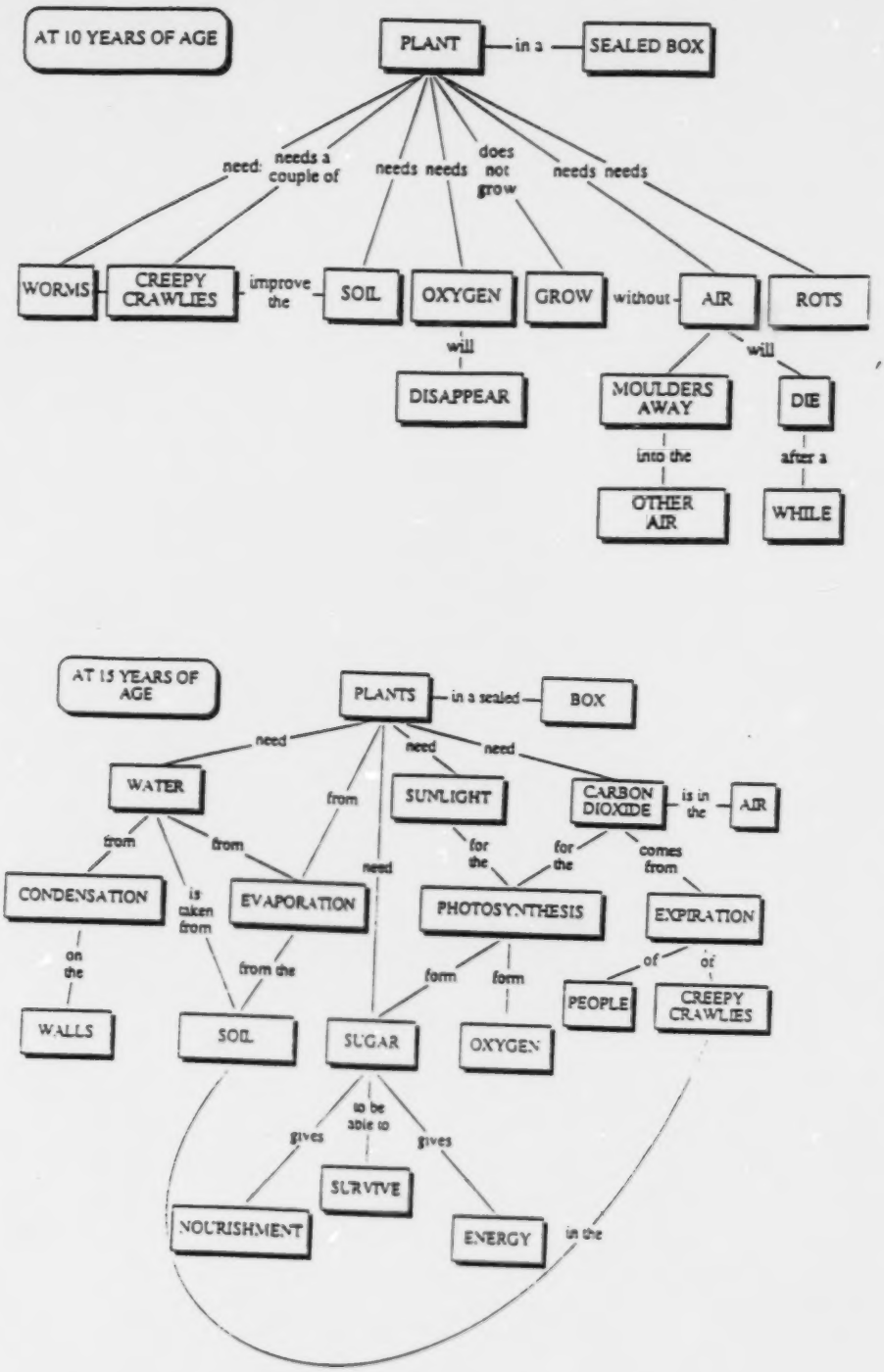

Fig.1. Concept maps drawn from interviews about conditions for growth with a student at 10 and 15 years of age.

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ANALYSIS

All of the interviews were audiotaped and transcribed verbatim. Concept maps were constructed from the interview transcripts according to a design that has been developed at Cornell University (Novak, 1998). See figure 1. Ausubel's theory of meaningful learning had important implications for the analysis of the interview data and for the description of the students' differential conceptual development (Ausubel, Novak & Hanesian, 1978). By comparing the concept maps and the transcripts from the interviews with each student through the years, I have identified developmental patterns in the structure and content of the students' conceptions.

The focus of the current research project has been to identify personal contexts and continuity of thought in the students' conceptual development. Specifically, I have sought to explore examples of learning as a part of a social practice that then had been integrated into the learners' ideas and how such examples of situated learning could develop through the years. I also wanted to know how the students themselves interpreted such elements in the interviews.

FINDINGS

During the analysis of the interviews over the years, it has been possible to recognize personal themes in the students' conceptions about ecological processes. Such themes can have a structural nature – a way of explaining a phenomenon through the years. Other themes can concern the content.

About conditions for growth

As an answer to the question: "What do you think will happen to the plants in the sealed box?" most students said at the first interview that the plants would die because they lacked access to life supporting resources like water and air or oxygen. The students thought that the plants must take in matter of different kinds from the environment but did not consider the passing of matter flowing through the plants. In order to understand what was going on, the students described a 'use up model' that meant that the plant was the 'end point' for the necessary resources. Hanna expressed it the following way, *'They take it in and then they don't get any more and they wither. They can't flower. The air only comes to the plant.'*

The teacher heard the children discuss the plants' chances of survival and possible sources for all the water that covered the walls and the lid inside the box. Therefore, she introduced a 'cycle model' to explain why there could be so much water although they had not seen it when they started the cultivation. Many students picked up that 'cycle model' and started to discuss the plants' possibility to survive from a new perspective. A new structure in the interviews can be identified. The students described individual 'cycle models' as themes during the subsequent interviews to explain how the plants in the sealed box could maintain water, air, oxygen and carbon dioxide. Many of them transferred the water cycle model to be a valid description of the cycle of other substances. Many of the descriptions were not scientifically correct like in the following segment from an interview with a twelve-year old student: *'If the water then rises and then rains down, then there will be air. They get air in that way.'*

In most cases the twenty-three students' descriptions became more developed through the years. However, it is possible to recognize personal features in the students' conceptions like in the following segments from interviews with Eric. After the teacher's introduction of a cycle model, Eric used a 'cycle model' to explain why the plants could survive in the sealed box. His 'up and down description was replaced by a description in fewer words at 13 and 15 years of age, but he did not differentiate between air and water until he was 15 years old.

Eric at 10y
'It will be wet 'cos nothing comes out and the air tries to get out. And there will be water. It evaporates.

Eric at 10y (After the introduction)
'It is sort of vacuum in there. The air evaporates but then it goes down again. And there will be air again. Up and down, up and down. The air rises, evaporates and becomes water. Then it falls down again and there is water there on the ground. Then the air comes up again.

Eric at 11y
'The air disappears down into the soil and there is more nourishment. Then it goes up again. Then it goes up and down, up and down'

Eric at 13y
'It is shut up sort of... The air in there has become ... It is warm so there was steam of it.'

Eric at 15y
'It circulates all the time. Before you put the lid on, you water before. Then it evaporates and settles on the lid.'

Eric said at 11 years age that the air got nourishment from the soil. Several students in the class looked upon the soil as a container of different life supporting resources. This idea appears like a theme in the interviews with Emil concerning the need for oxygen. In the interviews at 10, 11 and 15 years it is very clearly expressed that the plant gets its oxygen from the soil. At 15y he said, *'Doesn't the soil absorb the air, and then the soil gives it to and the flower the grass.'*

Tove's concern, at 10 years of age, was the plants' need for oxygen in the sealed box. When I asked her what she thought about that she answered, *'If you think you have plants, it's difficult, you can have plants in plastic bags. And then there will be steam, so perhaps they make it.'* When I asked her if this had something to do with oxygen she said that she did not know. She used what was going on in the plastic bag as some kind of prototype for a process that could provide the plant with necessary resources. After the teacher had introduced water cycle as an explanation model for what happened to the water in the sealed boxes, Tove preferred to use cycle explanations when she was asked about plants' possibilities to survive in the boxes as we can see in the following interview segments.

Tove at 10y
Water vapor comes from the moisture in the soil. The soil is wet and then it circulates.

Tove at 11y
They need light. Then they don't need more than the moisture that is in there. If it is sealed there will be a cycle and it goes round.

Tove at 13y
S: *Well, we breathe out carbon dioxide. We breathe in oxygen and the plant breathes out oxygen to us.*
I: *But if you think it is enclosed there in the box?*
S: *I don't understand but there must be a little cycle in there.*

Tove at 15
The water evaporates and then falls down. It is somehow a cycle. It is like the earth but in miniature.

Personal themes can not only concern the structure of the students' conceptions but also the content. Already at the very first interview with Oscar about conditions for life, he argued that the plants needed creepy crawlies in the soil. He expressed the same argument in the interviews at 11, 13 and 15 years of age. In fact this idea helped him to understand how the plants in the sealed box could get carbon dioxide. *'Perhaps somewhere from the soil. There are small animals that perhaps breathe so there will be carbon dioxide.'* See figure 1.

When Sofia explained why the plants could survive in the box, she always described in illustrative way how the water cycle could provide resources for many of the plants' needs. Her ideas were always mentioned the concept of dew as part of the cycle.

Sofia at 10y
S: The water rises up through the stem.
I: And where does it go then?
S: It becomes dew.
I: Well, what happens with it then?
S: It rises up and rains down.

Sofia at 11y
'Well, first you poured in water. Then in the morning, there sort of will be dew on the leaves and the, when it is a little warmer in the box, it rises up towards the floor. And then it is raining down when there is too much.'

Sofia at 12y
'Well, first there will be dew on the leaves. Then it rises up here and then it falls down on something down there.'

Sofia at 15y
'You had watered the soil before you planted them and had sealed the box. The plants absorb the water. Then there is dew on the plants that evaporates. It rises. Therefore, it is condensation there. And then it runs down back into the soil.'

Sofia was the only student who used the concept of dew in her descriptions. At 19 years of age, she expressed the following comment after having listened to the earlier interviews with her: *'It's from childhood. The dew has always fascinated me. It is unbelievable beautiful.'* There was an experience of situations during childhood that had become an important element in her ideas about the water cycle.

About decomposition of leaves

The interviews about decomposition started with the question – What do you think will happen with the leaves on the ground? Several students seemed to have a core idea, a personal theme that can be followed through the years also in the interviews about decomposition. Sten mentioned for example at 11, 13 and 15 years of age blowing as the important process that turned leaves into soil. In the following interview segments we can see that Emil had another way of describing the decomposition of the leaves on the ground. He willingly described how the leaves were crumbled into pieces and then went into the soil without mentioning any organism activity.

Emil at 11y

'Well, they grow down into the soil and then at last they turn into soil. They become older and older and when they have fallen down they crumble into pieces. Well, it becomes soil.'

Emil at 13y

' Well, then they are lying there on the soil for some time. Then they become ....., soil covers them and sort of. Then they rot and become soil.'

Emil at 15y

'Well, it lies down on the soil and then it rots, that means that it goes down into the soil. Then it becomes soil. When the leaves go down into the soil, they are crumbled into pieces.'

When Emil as a 19 year-old listened to earlier interviews with him, he said that his way of describing what happened with the leaves could be a result of the frequent walking together with his family in the woods in the autumns as a boy. He said, *'I saw how the leaves covered the ground everywhere. Later on there were none of them left. Then I thought they had gone down into the soil.'*

Also Anders described the decomposition of the leaves on the ground as fragmentation without mentioning anything about organisms involved in the process. He always in someway referred to composting and described this process in a rather detailed way. For example, from 9 to 13 years he always mentioned that you can put eggshells on the compost. Here follow segments of the interviews with Anders at 11 and 15 years of age.

Anders at 9y

'Quite a lot of soil comes from leaves. Eggshells ..... Soil comes also from coffee grounds and sort of thing, rots and becomes soil.'

Anders 11y
S: *'Well, they have dried. Then they haven't had enough water and then ..... You put many other things there, you can also put eggshells and so on the compost heap. And they stay there and rot in some way. It takes a long time, it takes just about four years to get real and very nice soil.'*
I: *'Do you have any idea how in fact it works?'*
S: *'I think there's water and then it rots and then it becomes soil 'cos there is soil underneath that's been there for a long time. And I think it is mixed with that so there will be even more.'*

Anders at 13y
'Soil's made of mainly sticks and gravel and that sort of thing. Something else that can dry and become soil can be eggshells and the sort of things you put on the compost. That becomes soil.'

Anders 15y
'It is like composting. You have some soil on the bottom and then it stays there becoming smaller and smaller bits. I think it's the same with the leaves, that they are mixed up and then there'll be more and more of it. I don't think that there'll be soil but I think there will be small, small bits that is mixed up with the soil, then you say that it has become soil.'

When Anders heard this at 19 years of age he smiled and said: *'We had a neighbor who carried out composting in a special way. I liked to be there together with him. The man even put eggshells and coffee grounds on the compost. I remember the first time I was there. And he asked me to empty a bucket with coffee grounds and some eggshells on the compost heap. I was confused. I think I was 7 years old.'* This powerful experience seemed to have influenced Anders' thinking about decomposition but it did not help him to develop his idea. He did not develop a conception where organism activity was an important part the process. Perhaps the powerful experience of the 'mixing process' in the bottom of the compost became an obstacle for a development of a deeper understanding.

In the following segments of the interviews with Hanna about decomposition of the leaves we can follow a characteristic feature in her descriptions from 9 to 15 years of age. There is one theme through the years that concerns raining and drying that still exist even if other perspectives are connected to this core idea. At 13 and 15 years of age Hanna included organism activity in her descriptions about decomposition of the leaves but still we can recognize the core idea from earlier years.

Hanna at 9y
'Some of them sink down into the mud when it's raining. They dry out in some way and shrivel up. Then when they are completely dry. It is enough for it to rain just once more for them to become just small bit.'

Hanna at 11y
'I think they mould away. The will dry out ... then an animal is coming, trampling them and they become broken. It will become small, small pieces and then the real soil is pressing them down and they will be a lump and then it is raining and the sun is shining and it becomes soil.'

Hanna at 13y
'They dry out and perhaps it rains so that they become soft. Then they dry out again. Then in the end they become and animals start eating them. Then you get soil of it.'

Hanna at 15y
'It must be when it dries up. Then when it rains, it is mixed up with some mud. Then it dries and becomes soil. Or also some animals come and eat it. Their excrements will become soil'

After Hanna had listened to earlier interviews with her as a 15 and 19 year-old, she explained why she described the process in that way. Near the house where she lived with her family were two big birch trees from which lots of leaves fell down to the ground every autumn. At 19 years of age, Hanna said that she remembered how she after a rain liked to go out playing by mixing soil and water to mud even if she did not like to be awfully dirty.

About defoliation
The interviews about defoliation started with the question: "What makes the leaves fall from the trees in the autumn?" In many cases the students combined different reasons of defoliation when they explained the phenomenon. When I analyzed the students' conceptions about this phenomenon, I found it possible to identify continuity in the development of the descriptions of defoliation in several students' statements. The students changed from a more 'leaf-centered' view at 11 and 13 to a more 'tree-centered' view at 15 years of age. Explanations as a result of physical causation like wind and frost were more common at the earlier interviews. At the age of 15y physical causation was replaced by ideas about lack of resources coming from inside with nourishment as the most common resource mentioned. It is possible to follow such a progression in the following segments from the interviews with Oscar about defoliation.

Oscar at 9y
'It doesn't get any water. Or it has no muscles left to be able to stay on the branch'

Oscar at 11y
'They don't have the strength remain sitting there. They must jump off.'

Oscar at 13y
'They fall at autumn and they want much sun. Well, perhaps the tree has not the strength to carry them any longer. It has enough to do getting nourishment themselves, and it drops the leaves.'

Oscar at 15y
'Well, it is ..... during winter the tree cannot give nourishment to the leaves and itself, so it drops the leaves. It closes the supply of nourishment to the leaf, doesn't it. Then they die and drop.'

Besides the continuity in the students' descriptions of defoliation, it is in many cases possible to define a personal theme that comes back year after year. Such a theme can

concern the age of the leaves as in Ruth's descriptions according to the following interview segments. The renewal of the foliage was important elements in her ideas that are evident in the following interview segments.

Ruth at 9y
'The leaves fall because it has been cold.'

Ruth at 11y
'Cos' there will come new buds and the others have been hanging there for their time.'

Ruth at 13y
'Well, it is because there will come new fresh leaves. The are old and brown, and when they don't get enough with oxygen so to say the must fall.'

Rut at 15y
'Yes, it is in the autumn ..., the trees drop them cos' there shall be something new for the summer, so to say. If they remain sitting there it will not look that fresh, so to say.'

About the role of the flower
Some students continued to express anthropomorphic explanations as personal themes year after year, especially concerning the defoliation and the role of the flower in plant reproduction and. In the following segments of the interviews about the role of color of a flower, Anders describes his ideas with strong anthropomorphic features. The interview started with the question, - What is the importance for a plant to have a flower with color? During the interview at 15 years of age, Anders had a little daisy growing in a sealed box in front of him and not as on the previous occasions a bunch of wild flowers in a glass jar.

Anders at 11y
'I think the flowers have ..... cos they have colors to make you think they are nice and want to have them indoors. It gives you something to embroider the table with when you have guests. Then the food on the table and then you embroider the table with some brightly colored flowers.'

Anders at 13y
'I think there is a thought behind it just like we as human beings, that I want to look nice and that I don't want .... So if you know to put on something, just as human beings put on things. We comb our hair and so on. So I think to have nice colors so that people and others think they are nice. Just like we want other people to think that we..., that I look nice. That's what I think.

Anders at 15y
'Well, actually I've wondered about that too, but I think it's like a human being, they need all this growing around them and the leaves. Life's a bit nicer and not so boring. It is like human beings. We live in our houses. We plant plants and have other things 'cos it makes it nicer. I think that .... what plays a big part for them to have a flower is that the leaves are not alone. The flower is company for them which makes it nicer for them to grow up. Perhaps it makes them stay on longer 'they're having a nice time.'

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At 19 years of age, when Anders had listened to the interviews with him at 11 and 15 years of age, he still described the role of the flower in an anthropomorphic way when I asked him: *'I think I have the same idea to day. A plant has a soul like us. The plant want to have the feeling to look nice.'*

Oscar willingly used anthropomorphic formulations when he talked about different phenomena in nature as we already have noticed in his descriptions of defoliation. He also expressed anthropomorphic and human-centered a ideas to explain the role of the flower at 11 years of age, though he used the anthropomorphic ideas as analogies rather than as explanations. Such features in his formulations were still present at the age of 13y. At 15 years of age he had developed a more scientific explanation. As in the case of defoliation, there is continuity in Oscars' approach from anthropomorphic ideas towards more 'scientific' explanations. Oscar carried with him a way of describing the phenomenon in different contexts through the years.

Oscar at 11y
'In order to attract animals that can then suck nectar from inside there so that they can reproduce or perhaps they can boast to the other flowers and make themselves beautiful and so on in the same way as women powder themselves and so on. If you have them in a garden, perhaps you water them very much more cos they are so pretty.'

Oscar at 13y
S: 'To attract bees and such so it can grow better.'
I: 'What does it mean that it can grow better?'
S: 'That there will be a bigger family. It will be more diluted and not extinct. Nobody wants to have anything to do with an ugly flower but you can try to plant a pretty flower more and so.'
I: 'What role do the bees play?'
S: 'They make it flower. Well, they suck out something. And there is a scale or something like that inside the flower of which they can make honey. And they spray something else in or something like that and it flowers in any case.'

Oscar at15y
'It's in order to be able to attract the wasps. And then they suck the nectar or something and so the stuff gets stuck, pollinin..... No, I don't know what it is called. Perhaps that is what it is called and then they take it with them and so it goes on to the next flower. The flower can't be fertilized from the same stamen there down in the seed, it must sort of change flowers. These stick to the wasp and are carried on and go down into the seed. And a new embryo is formed in there that falls out or when it withers, it stays there.

At 19 years of age after he had listened to earlier interviews with him, he claimed that the anthropomorphic features in his descriptions about defoliation and the role of the flower could be a result of his mother's way of explaining the phenomena to him. She willingly used anthropomorphic description when explained different phenomena. He said that he knew as a boy that the leaves did not have muscles. It was a way of explaining why the leaves fell down from the trees in autumn. Also in other cases, he referred to his parents as important for the development of his understanding of ecological processes in the early ages.

DISCUSSION

The students focused in this study different things in their answers during the interviews about ecological processes, and there was a rich individual variation of conceptions among the students. The longitudinal design of the present study has made it possible to identify personal themes in the students' explanations through the years. Several students expressed the same core idea year after year when they were asked to explain a phenomenon. Mostly, the students did not use the same words but the same idea that indicate a continuousness in their thinking.

Individual themes in students' ideas could be of a structural nature, a way of explaining a phenomenon. The teacher introduced a 'water cycle model' early at school in order to explain why there was a water film on the walls inside the vivarium. Many students applied this model not only to describe the water cycle but also to describe cycles of different kinds of matter in an attempt to understand why the plants could survive in the sealed boxes. Their explanations were often inconsistent with the scientific view. Personal themes of structural nature have also been identified concerning the students' descriptions of the decomposition of leaves on the ground. This is more obvious in some cases than in others. Hanna mentioned every interview how rain and sunshine contributed to the decomposition of leaves on the ground. Another personal structure that is possible to follow through the years in the students' descriptions is of anthropomorphic nature that students willingly used on different occasions order to understand and describe the phenomena.

It has also been possible to identify individual themes that concern the content of the students' statements. Oscar stated year after year the importance of soil invertebrates for the plants to survive in the sealed boxes. Sofia's always used the concept of dew as a part of her explanations.

When the students, as 15 and 19 year-olds, listened to what they said in earlier interviews, they could not only identify such themes. In some cases, they could tell how such a theme built upon a concrete experience in childhood. Learning was situated in the meaning that the student's learning was related to the context where she/he had made the experience, but what was learnt became then an integrated part of the learner's thinking. Like in Hanna's case concerning her ideas about decomposition, many students did not replace one understanding with another one. Instead, they widened their ranges of ideas or increased their repertoires of ideas (Marton, 1998). However, a core idea developed at an early age seems to be an important unit in many students' repertoires of ideas. There seem to have been powerful experiences in the early ages that made it possible for individual features to exist in spite of all influences while growing up. Even if there was a substantial conceptual development, there was also a very strong element of personal context and continuity in the students' thinking about the ecological processes.

I argue that besides the contextual variation, there is a personal context and continuity that has important implications for the learning process. When the students listened to what they said about the biological phenomena in earlier interviews, they could reveal particular events that they had experienced together with other persons, such as parents, playmates and neighbors. The experiences were traced back to social

situations that had become a part of the students' personal inventory. The students had their personal biographies through which they saw the world.

Sfard (1998) claims that educational research of today is caught between two metaphors that she calls the 'acquisition metaphor', representing the cognitive perspective and the 'participation metaphor', representing the situated perspective. She means that the difference between the two perspectives is not a matter of differing opinions but rather of participating in different, mutually complementing discourses. From my point of view learning cannot only be described as a participation in a social practice. It is also important to pay attention to what goes on in an individual's mind. My study has been carried out from an 'acquisition metaphor perspective'. I have found that several students carried with them individual ways of describing biological phenomena. I have studied the development of the students' conceptions and what might have happened in individual students' thinking. Many students could as 15- and 19-year-olds reveal personal reasons why they said as they did, after listening to earlier interviews with them.

I think there are great possibilities improving science education by creating an atmosphere that gives students opportunities to recognize and discuss their personal conceptions of scientific phenomena and compare them with other alternative conceptions. My study has shown that early experiences of different phenomena seem to play an important role in the development of many children's conceptual understanding later in life.

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